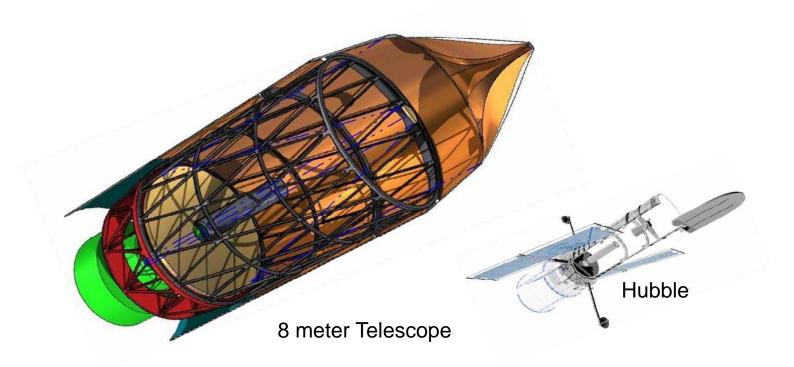


8-meter UV/Optical Space Telescope at L2

H. Philip Stahl, Ph.D. NASA MSFC





Executive Summary

The unprecedented volume capability of an Ares V enables the launch of 8 meter class monolithic space telescopes to the Earth-Sun L2 point.

The unprecedented mass capability of an Ares V enables an entirely new design paradigm – Simplicity.

Simple high TRL technology offers lower cost and risk.

NASA MSFC has determined that a 6 to 8 meter class telescope using a massive high-TRL ground observatory class monolithic primary mirror is feasible.



Design Concept

8 meter Monolithic Telescope & tube can fit inside Ares V 10 m envelop.

Minimize Cost (& Risk) by using existing ground telescope mirror technology – optics & structure.

8-meter diameter is State of Art

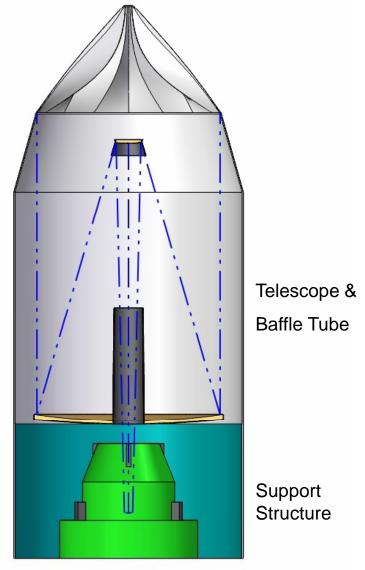
9 existing: VLT, Gemini, Subaru, LBT

23,000 kg (6 m would be ~13,000 kg)

~\$30M (JWST PM cost ~\$120M)

7.8 nm rms surface figure (~TPF spec)

Expect similar savings for structure



Spacecraft & Science Instruments



6 meter Optical Design

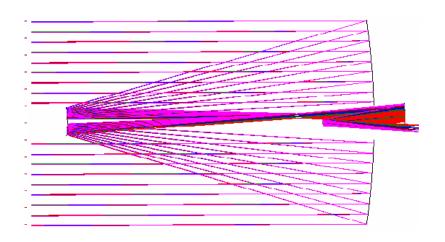
Ritchey-Chretién optical configuration F/15

Diffraction Limited Performance at <500 nm
Diffraction Limited FOV of 1.22 arc minute
(10 arc minute FOV with Corrector Group)

Coating: Aluminum with Mg F2 overcoat

Average transmission > 63% for wave lengths of 200 to 1,000 nm

Primary to secondary mirror vertex: 9089.5 mm Primary mirror vertex to focal plane: 3,000 mm





0.8

0.7

Lycondy 0.5 0.4 0.3

0.1

Three Mirror Anastigmatic

With Fine Steering Mirror

Multi-Spectral 10 arc min FOV

Spectral Throughput

Wavelength [nm]

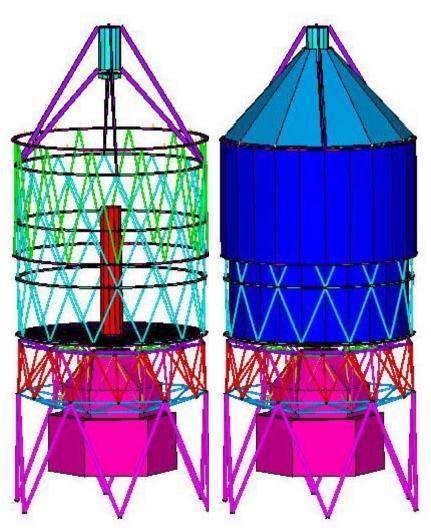
Reduced Throughput



Structural Design

Operational

Launch Configuration



Tube is split and slides forward on-orbit.

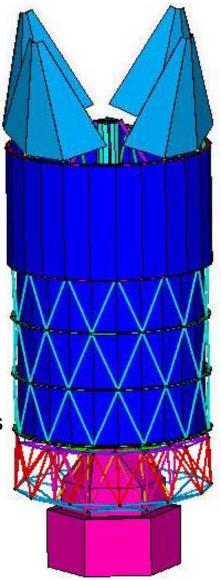
Faster PM or taller shroud may allow for one piece tube.

Doors can open/close

Forward Structure is hybrid of Hubble style and four-legged spider

Truss Structure interfaces with 66 mirror support attachment locations

Launch Structure attaches Truss to Ares V





Structural Analysis

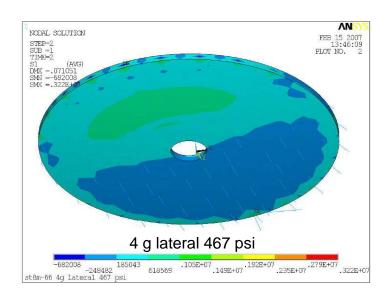
Launch loads: maximum values from POST3D (not concurrent)

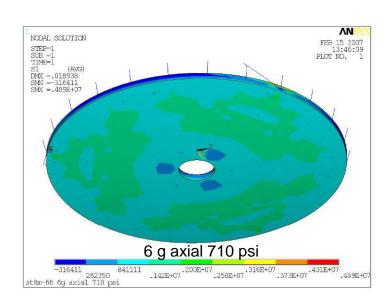
Axial: 4 g's

Lateral-y: 7×10^{-6} g's

Lateral-z: $6 \times 10^{-4} \text{ g's}$

8.2 meter 175 mm thick meniscus primary mirror <u>can survive launch</u>. 66 axial supports keep stress levels below 1000 psi

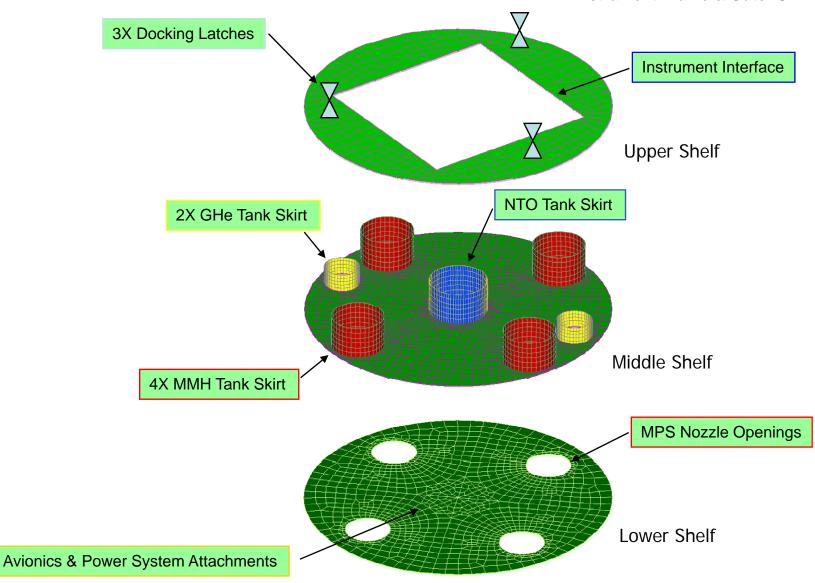






Spacecraft Structural Modeling

Instrument Frame & Outer Skin Not Shown





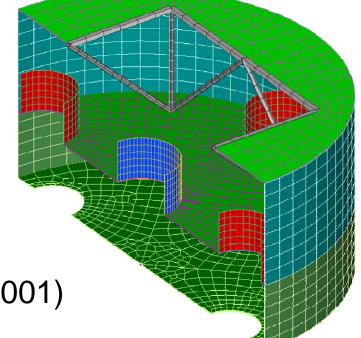
Spacecraft Structural Analysis Assumptions

Launch Load Case: 4.0g Axial + 2.0g Lateral

Materials: Metallic Structure Only

AA 2219 for plate elements

AL 7075 for Beam Elements



Factors of Safety: (per NASA-STD-5001)

Yield Factor of Safety: 1.1

Ultimate Factor of Safety: 1.4

Cross-Sectional View of Spacecraft



Structural Model Results

Upper Shelf:

Shelf: Isogrid Panel 0.090" (minimum pocket thickness)

Middle Shelf:

Shelf: Isogrid Panel 0.060" (minimum pocket thickness)

MMH Skirts: 0.064" thk NTO Skirt: 0.088" thk GHe Skirt: 0.040" thk

Lower Shelf:

Shelf: Isogrid Panel 0.060" (minimum (pocket thickness)

Instrument Support Frame:

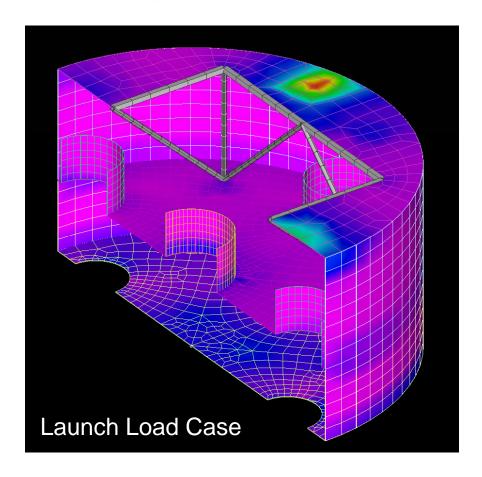
Upper Support: "T" Beam, 0.095" thk

Uprights: 2" diameter, 0.030" thk

Angled Supports: 1.75" diameter, 0.030" thk

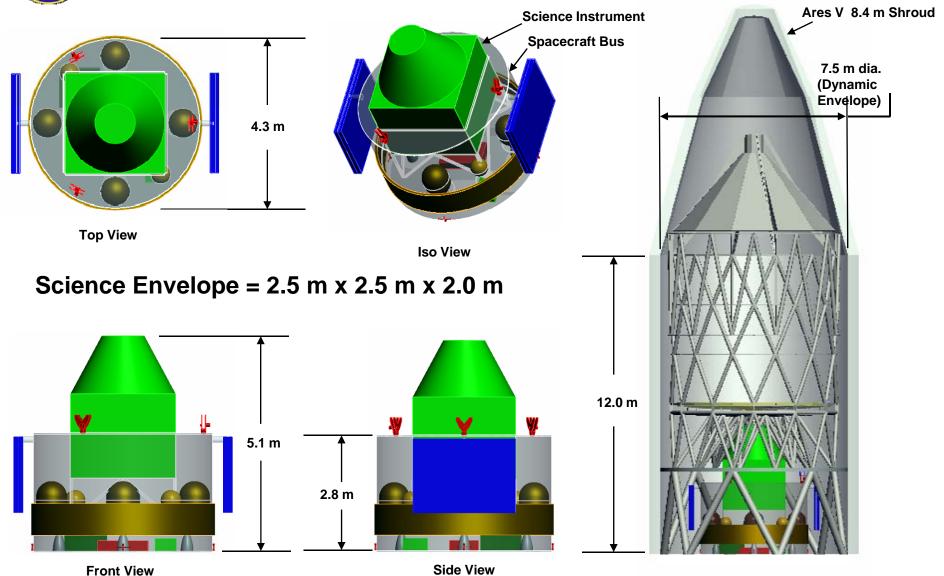
Outer Skin:

Upper Outer Skin: 0.26" thk Lower Outer Skin: 0.21" thk





Spacecraft Design Detail & Shroud Integration



Front View

NOTE: All dimensions are in meters.



6 meter Preliminary Mass Budget

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	mal Management Sy	vstem	480	E163		
	ctures	y Storii	755	estimate	WAG	
	dance and Navigation	2	50	estimate	50% WAG	
	oulsion	-	250	El63	3370 11713	
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	king station		1,000	estimate	WAG 38%	Mass I
	J. G. Station		.,550	- Communication		
ience	Instrument	t W / Bus mass	s 6,275			

8 meter Preliminary Budget is 45,000 kg (~20% Reserve)



Thermal Analysis

Spacecraft wrapped with 10 layer MLI blankets

16.0 m² thermal radiators

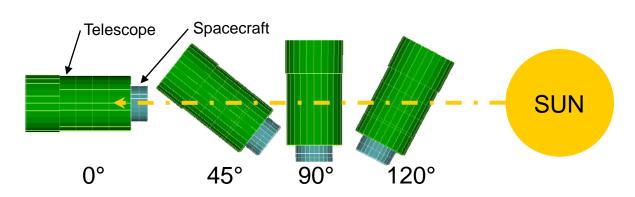
Load Cases

0° (base)

45°

90° (broadside)

120°





Spacecraft Thermal Analysis

Solar Flux at $L2 = 1296 \text{ W/m}^2$ applied to base

Instrument Heat Output = 750 W

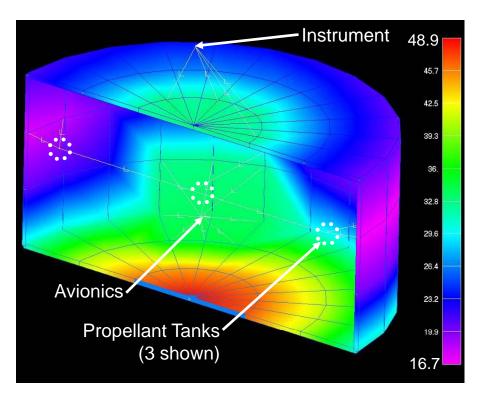
Avionics Heat Output = 850 W

Propellant tanks modeled as single nodes with heat leaks from the spacecraft walls

Steady-state operational temperatures determined

Spacecraft wrapped with 50 layer MLI blankets

16.0 m² thermal radiators

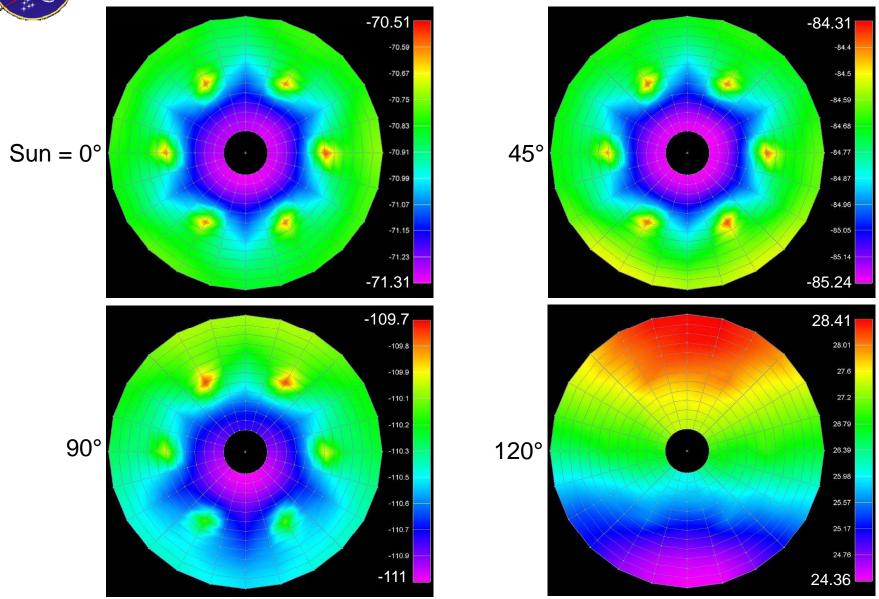


Temp in °C

Propellant tanks maintained with MLI and heaters
Heaters required to keep propellant from freezing

NASA

Primary Mirror Thermal Analysis Results



^{*} Temperatures are in °C. Note varied temperature scale for each load case.

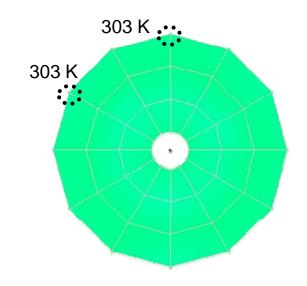


Primary Mirror Thermal Analysis

Active Thermal Management via 14 Heat Pipes yields a Primary Mirror with less than 1K Thermal Variation.

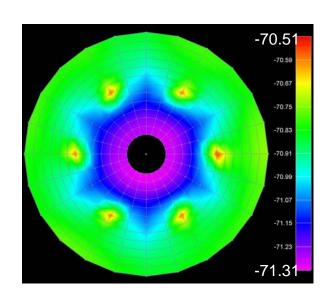
No Thermal Management yields a Cold PM

Sun Angle Temp
0 deg 200K
90 deg 160K
120 deg 300K
with 1K Thermal Variation



Thus, possible End of Life use as a NIR/Mid-IR Observatory.

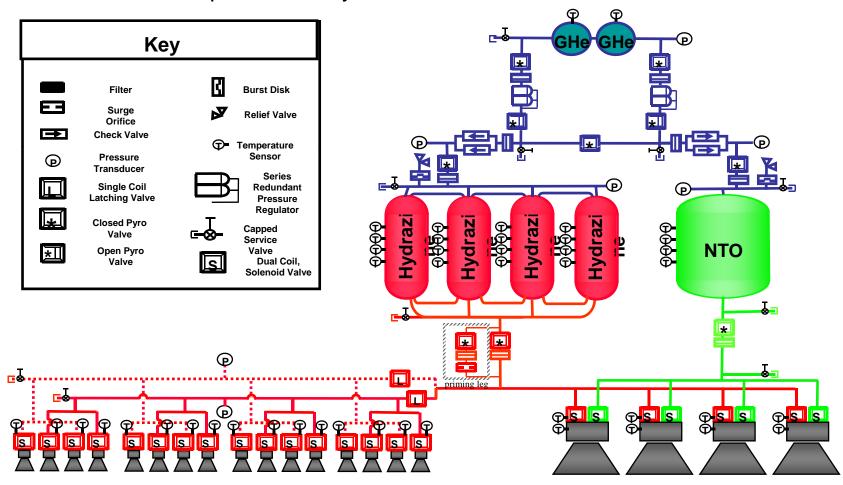
Figure Change will be driven by CTE Change from 300K to 150K Zerodur CTE is approximately 0.2 ppm. SiO2 CTE is approx 0.6 ppm.





Notional Spacecraft Propulsion System

Dual Mode: Hydrazine-NTP Bi-Prop / Hydrazine Mono-Prop Propellant for 5 yr mission with redundant Thrusters

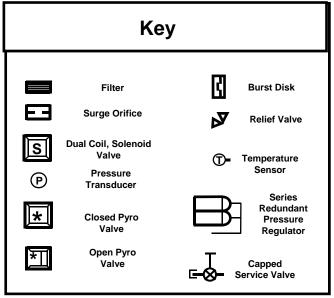


Hydrazine Mono-Prop with RCS 20/5 lbf Thrusters (Aerojet) for Station Keeping

Hydrazine-NTP Bi-Prop with four 125 lbf Thrusters (Northrop) for trip to L2



Notional Telescope Propulsion System



Telescope has Independent Control System

Mono-Propellant Hydrazine

Trade Analysis:

Refueling (Orbital Express) = 40 kg 30 Year Propellant Supply = 30 kg Hydrazine

350 – 100 psi blowdown
Aerojet Thrusters

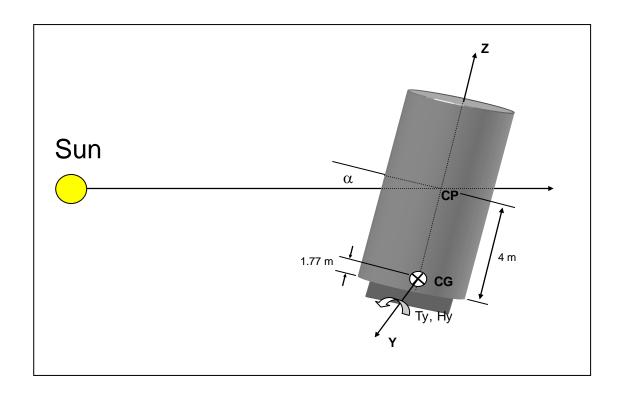


Guidance Navigation and Pointing Control

Spacecraft Reaction Wheels provide all GNC

Worst condition for solar radiation pressure torque is at sun angle = 90.

Momentum buildup occurs in one axis (y-axis)





GN&C Analysis

Two performance Parameters were analyzed and plotted against each other:

- Hours that Telescope can stare at a fixed point (remain at an inertial hold) before needing to perform a momentum dump due to solar radiation pressure torque
- How fast in minutes the Telescope can perform a 60 degree slew

6 wheel and 4 wheel configurations were analyzed along with the worst case single wheel failure for each configuration.

Each configuration was analysis for three different TELDIX reaction wheel versions with different (Torque : Momentum Storage)

Analysis

is only for the worst case sun angle = 0

As the sun angle increases so does the available science time.

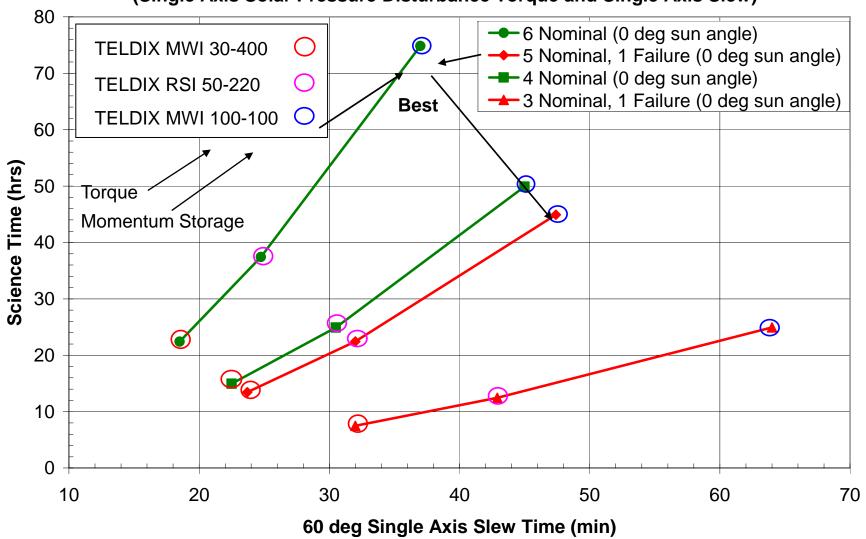
did not account for any solar panel contribution to solar pressure cp location.

This is worst case since accounting for the solar panels would move the cp location closer to the cg. Also, Telescope geometry is preliminary and may change due refinement in design



GNC: Reaction Wheels

Science Time vs Slew Time
6 and 4 Reaction Wheel Configurations
(Single Axis Solar Pressure Disturbance Torque and Single Axis Slew)





Avionics and Power Systems Assumptions

Spacecraft

Avionics

- •Spacecraft avionics systems are 1-fault tolerant for 5 year life
- •Guidance and navigation system includes star trackers, sun sensors, and IMUs
- •AR&D consists of a LIDAR long range system, and an optical short range system
- •Computers handle all normal station keeping, maneuvers, data management, and ground communications
- •Communication systems consist of Ka-band HGA for ground, and s-band for local comm and backup capability

Power

- •Spacecraft power systems are 1-fault tolerant for 5 year life
- •Power generation from two 9 m^2 deployable solar array wings with pointing ability
- •Batteries are sized for 2 hours of power for midcourse and rendezvous operations (with arrays retracted)
- •Spacecraft power system includes 800 w for mirror thermal control, and 750 w for telescope instrument package



Avionics and Power Systems Assumptions

Telescope

Avionics

- •Telescope avionics systems are 3-fault tolerant for 30 year life
- •Minimal guidance and navigation system, used only for station keeping during spacecraft exchange
- •Minimal computer capability, used mainly for station keeping during spacecraft exchange
- •All health and status data sent directly to spacecraft avionics system
- •Low gain communications capability with the servicing spacecraft only

Power

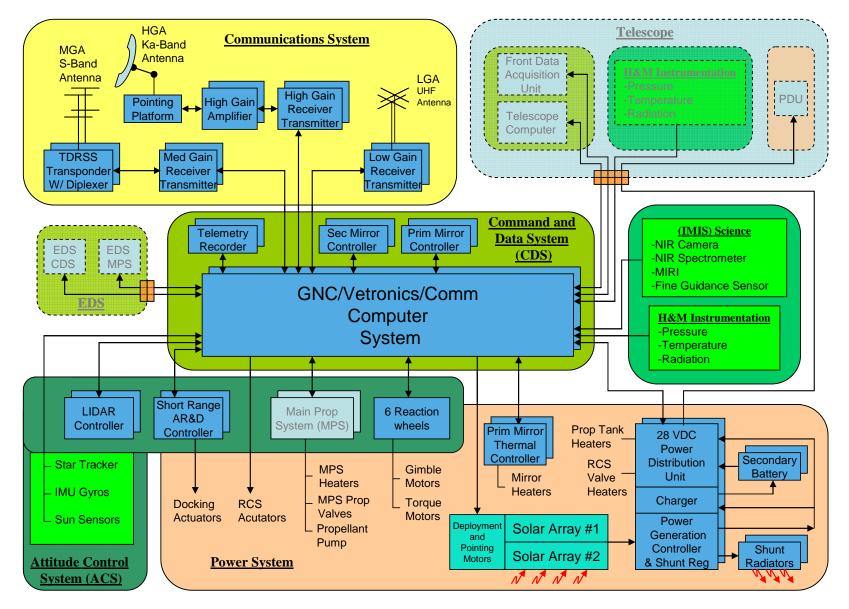
- •Telescope power systems are 3-fault tolerant for 30 year life
- •18 m^2 body mounted solar array around light tube, used for station keeping during spacecraft exchange
- •Batteries sized for 0.5 hour attitude control contingency
- •No active mirror thermal control during spacecraft exchange



Spacecraft Astrionics & Power Systems

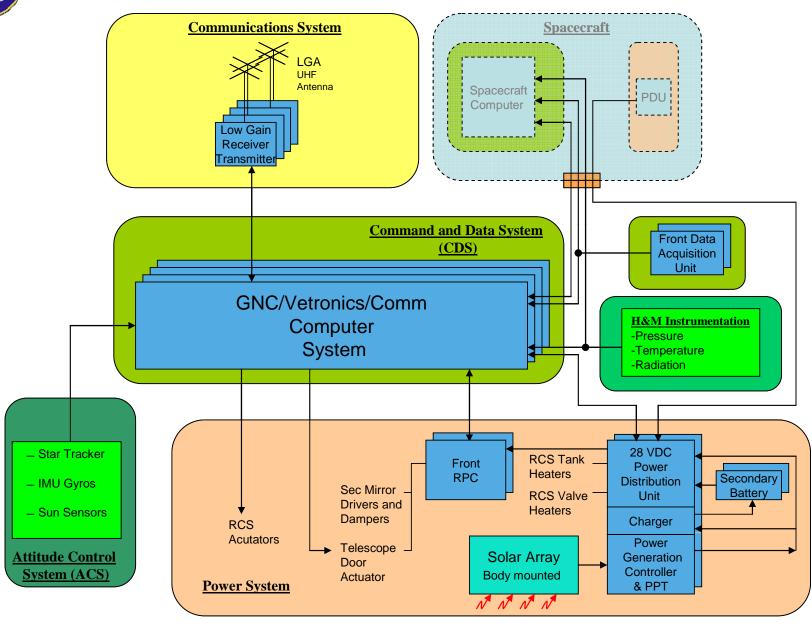
6m Telescope - Spacecraft Astrionics and Power Systems







Telescope Astrionics & Power Systems





Mission Life

Initial Mission designed for a 5 yr mission life (10 yr goal) should produce compelling science results well worth the modest mission cost.

But, there is no reason why the mission should end after 5 or even 10 years.

Hubble has demonstrated the value of on-orbit servicing

The telescope itself could last 30 or even 50 years.



30 to 50 year Mission Life

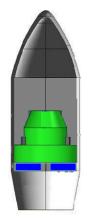
Copy Ground Observatory Model – L2 Virtual Mountain

Design the observatory to be serviceable

Telescope has no inherent life limits

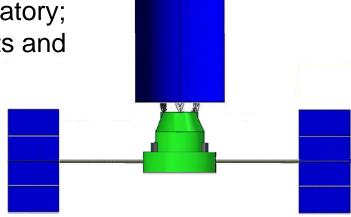
Replace Science Instruments every 3-5 yrs (or even 10 yrs)

Replacement Spacecraft in ELV Observatory has split bus with on-board attitude control and propulsion during servicing. (already in mass budget)



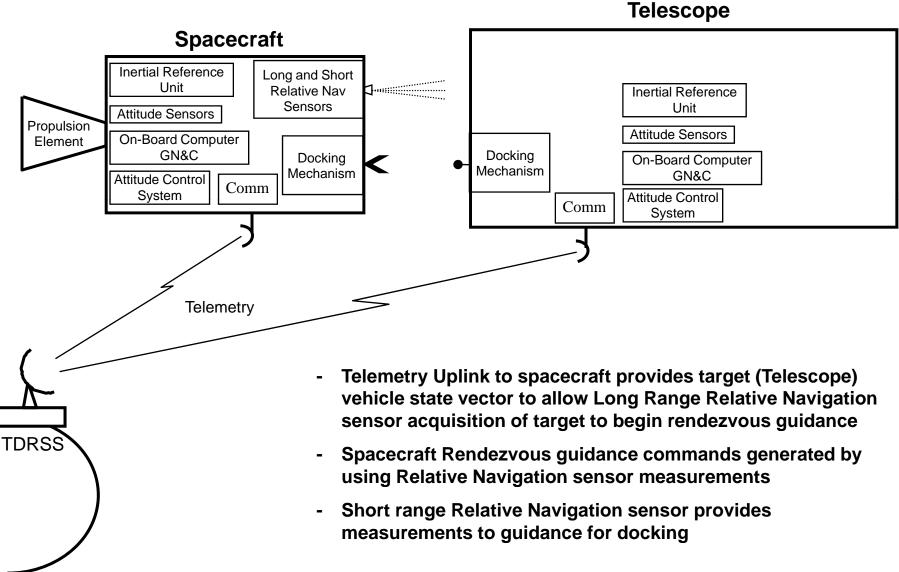
Autonomously docks to observatory; replaces all science instruments and ALL expendable components.







AR&D System Elements





Conclusions

The unprecedented mass/volume capability of an Ares V enables the launch of 8 meter class monolithic space telescopes to the Earth-Sun L2 point.

NASA MSFC has determined that a 6 to 8 meter class telescope using a massive high-TRL ground observatory class monolithic primary mirror is feasible.

Mature, High-TRL design enables early deployment.

Science Instruments, Expendables and Limited Life Components can be replace periodically via Spacecraft Autonomous Rendezvous and Docking.



Any Question?

